USDA Forest Service
Research Paper INT-79
1970

CONE AND SEED YIELDS IN YOUNG WESTERN WHITE PINES

R.T. Bingham and G. E. Rehfeldt

INTERMOUNTAIN FOREST AND RANGE
EXPERIMENT STATION
Ogden, Utah 84401

USDA Forest Service
Research Paper INT-79
1970

CONE AND SEED YIELDS IN YOUNG WESTERN WHITE PINES

R. T. Bingham and G. E. Rehfeldt

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401
Joseph F. Pechanec, Director

THE AUTHORS

RICHARD T. BINGHAM is leader of the Moscow, Idaho, Forestry Sciences Laboratory Research Unit studying Resistance to Blister Rust in Western White Pine. He is Acting Leader of another of the Intermountain Forest and Range Experiment Station's Research Units--Breeding Conifers for the Northern Rocky Mountains--that is also headquartered at Moscow. He has had broad experience in the pathology, silviculture, and genetics of western white pine; also, he is author of numerous publications on the genetics of blister rust resistance, and on the genetics of western white pine.

GERALD E. REHFELDT, presently a Plant Geneticist for the Intermountain Forest and Range Experiment Station, Moscow, Idaho, obtained his B.S. degree in Forestry from Utah State University in 1963 and his M.S. and Ph.D. from the University of Wisconsin in 1965 and 1967, respectively. His first assignment was at Moscow, Idaho, in 1967 and dealt with breeding of conifers for the Northern Rocky Mountains.

CONTENTS

ABSTRACT

Eighteen years of cone and seed yields from 179 30- to 50-year-old western white pines (*Pinus monticola* Dougl.) representative of 13 geographic localities were compared. Each tree averaged 28 cones per tree, and each cone contained about 104 filled seeds. However, not only was annual cone production highly variable, but geographic localities and individual trees varied greatly in productivity within a given year. Recognition of these components of variation in cone production for western white pine can lead to maximal efficiency in cone collection.

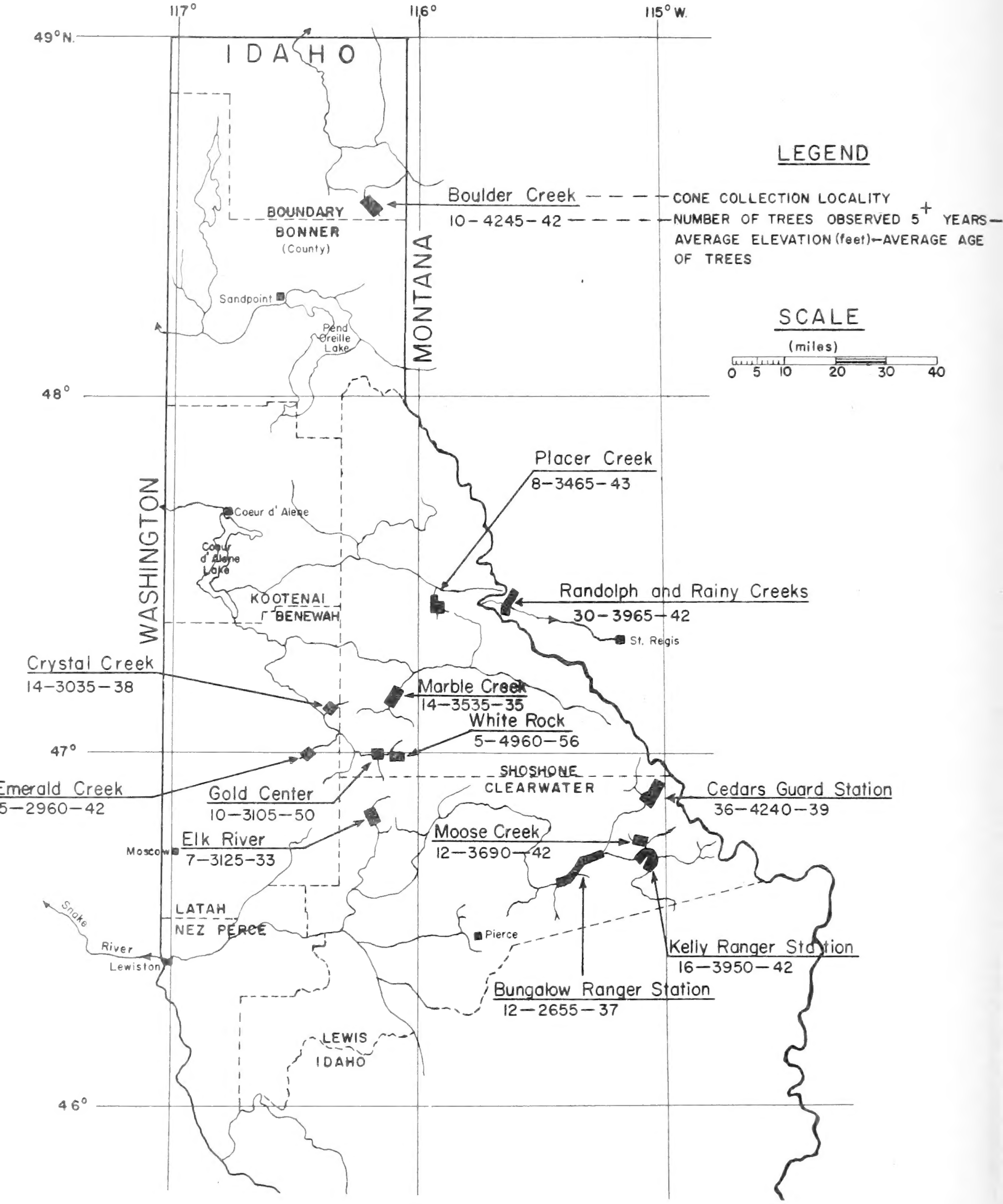

Figure 1.--*Map of northern Idaho illustrating the 13 geographic localities from which cones were collected and the number, average elevation, and average age of trees represented within each locality.*

INTRODUCTION

Forest managers normally recognize and anticipate periodicity in cone production of forest trees. However, variation in cone production among geographic localities and individual trees within localities is largely unexplored, for rarely are cones collected in consecutive years from the same trees.

In the course of breeding western white pine (*Pinus monticola* Dougl.) for resistance to blister rust (see Bingham, Olson, Becker, and others. 1969 and earlier), 18 years of data on cone and seed yields of individual trees from different geographic localities have been accumulated. The protection of cones during development minimized losses due to insects and rodents; therefore, these data simulate the full reproductive potential of young trees in natural stands. Annual variation in cone production among geographic localities and individual trees thus is represented in these data. This information is indispensable for practices of seed collection and seed orchard management which rely on knowledge relating to cone yields of individual trees and possibly on yields derived from controlled pollinations.

MATERIALS AND METHODS

During the years 1950 to 1967, cone and seed yields were obtained from 179 30- to 50-year-old western white pines. Trees were representative of 13 geographic localities (figure 1) within which they varied in elevation by about 400 feet; within two localities, however, trees differed in elevation by about 1500 feet.

Comparisons of yields between seed years, localities, and trees within localities were made on the basis of mean yield; statistical analyses were not attempted because yields for each maternal tree and locality were not available for each year. Criteria for including yields of individual trees in the basic data were: (1) five or more years of observation were available; and (2) observations were for consecutive or nearly consecutive years. Since periodicity in cone production of western white pine tends to follow 3- and 4-year cycles,[1] yields for each tree were represented for nearly all stages of cyclic production. It is therefore assumed that minimal confounding is represented in the data.

RESULTS AND DISCUSSION

Yield of Cones

At tree ages of 30 to 50 years, annual production of cones averaged about 28 per tree. This mean characterizes cone production inadequately because yield is subject to an interaction of exogenous and endogenous factors. The interaction causes tremendous variation in cone production among seed years, geographic localities, and maternal trees within each locality.

Within the 18-year period, mean yield of cones for individual seed years differed by as much as 55 cones per tree (table 1). In fact, the mean yield of cones per tree, in successive seed years, differed by as much as 34 cones. These differences in yield among seed years reflect a periodicity in cone production which is documented elsewhere in greater detail.[1]

Mean yield for geographic localities over all years of observation differed by as much as 64 cones per tree (table 2). However, the degree of difference between localities depended on the seed year. For instance, in 1967 which was a year of high mean yield, localities differed by as much as 78 cones per tree; but in 1956 when few cones were produced, maximum differences between localities were only 20 cones per tree. Thus, differences in yield among localities were evident, especially in years of high yield. Localities characterized by low cone yields, however, produced few cones even in favorable seed years.

---

[1]G. E. Rehfeldt, A. R. Stage, and R. T. Bingham. Time series analysis for production of female strobili in western white pine. Manuscript in preparation.

Table 1.--*Mean yields of cones per tree according to the seed year and the localities with the lowest and highest mean yield for each year*

	Yields per year		Yields per locality			
			Locality of lowest yield		Locality of highest yield	
Year	Trees observed	Mean (cones/tree)	Trees observed	Mean (cones/tree)	Trees observed	Mean (cones/tree)
1950	26	23.2	4	0	1	53.0
1951	29	27.8	4	2.0	12	50.6
1952	29	16.4	3	0	2	195.0
1953	38	18.2	5	0	5	74.4
1954	34	49.8	2	7.5	13	71.6
1955	7	40.8	1	22.0	1	55.0
1956	85	10.5	2	3.5	6	23.6
1957	11	16.5	1	5.0	5	27.0
1958	87	38.0	10	20.4	5	130.8
1959	87	28.3	31	18.5	4	159.5
1960	107	18.0	8	6.1	5	36.6
1961	146	21.8	3	3.3	9	60.9
1962	136	29.1	4	2.5	4	82.5
1963	119	25.3	4	0.8	9	86.2
1964	95	59.3	4	25.0	5	148.8
1965	91	40.3	2	28.5	5	84.0
1966	80	51.0	2	10.5	10	90.4
1967	76	65.3	3	21.0	10	99.0

Table 2.--*Mean yields of cones per tree for each year according to the locality, and the tree within each locality with the highest and lowest mean yield*

Locality	Trees observed	Mean years of observation	Mean (cones/tree/year)	Yield per tree: Tree of lowest yield		Yield per tree: Tree of highest yield	
				Years observed	Mean (cones/year)	Years observed	Mean (cones/year)
Emerald Creek	5	6.8	4.6	9	3.7	6	7.5
Gold Center	10	8.0	15.2	7	2.8	8	33.8
Placer Creek	8	6.5	16.2	7	4.6	5	55.4
Cedars Guard Station	36	7.2	20.5	6	0	6	89.1
Bungalow Ranger Station	12	6.6	22.7	7	4.0	10	58.1
Rainy and Randolph Creeks	30	7.4	23.4	7	0.6	11	69.8
Moose Creek	12	6.2	23.6	6	11.0	7	29.4
Elk River	7	7.1	30.3	6	6.0	12	46.1
Kelly Ranger Station	16	5.6	42.7	5	10.6	5	73.6
Marble Creek	14	5.8	55.2	5	8.2	8	122.9
Crystal Creek	14	11.1	56.1	8	1.6	18	129.7
White Rock	5	11.0	63.0	9	19.9	9	87.2
Boulder Creek	10	5.2	68.5	5	15.2	5	114.2

BINGHAM, R.T. and G.E. REHFELDT

1970. Cone and seed yields in young western white pines. USDA Forest Serv. Res. Pap. INT-79, 12 p.

Eighteen years of cone and seed yields from 179 30- to 50-year-old western white pines (*Pinus monticola* Dougl.) representative of 13 geographic localities were compared. Each tree averaged 28 cones per tree, and each cone contained about 104 filled seeds. However, not only was annual cone production highly variable, but geographic localities and individual trees varied greatly in productivity within a given year. Recognition of these components of variation in cone production for western white pine can lead to maximal efficiency in cone collection.

BINGHAM, R.T. and G.E. REHFELDT

1970. Cone and seed yields in young western white pines. USDA Forest Serv. Res. Pap. INT-79, 12 p.

Eighteen years of cone and seed yields from 179 30- to 50-year-old western white pines (*Pinus monticola* Dougl.) representative of 13 geographic localities were compared. Each tree averaged 28 cones per tree, and each cone contained about 104 filled seeds. However, not only was annual cone production highly variable, but geographic localities and individual trees varied greatly in productivity within a given year. Recognition of these components of variation in cone production for western white pine can lead to maximal efficiency in cone collection.

BINGHAM, R.T. and G.E. REHFELDT

1970. Cone and seed yields in young western white pines. USDA Forest Serv. Res. Pap. INT-79, 12 p.

Eighteen years of cone and seed yields from 179 30- to 50-year-old western white pines (*Pinus monticola* Dougl.) representative of 13 geographic localities were compared. Each tree averaged 28 cones per tree, and each cone contained about 104 filled seeds. However, not only was annual cone production highly variable, but geographic localities and individual trees varied greatly in productivity within a given year. Recognition of these components of variation in cone production for western white pine can lead to maximal efficiency in cone collection.

BINGHAM, R.T. and G.E. REHFELDT

1970. Cone and seed yields in young western white pines. USDA Forest Serv. Res. Pap. INT-79, 12 p.

Eighteen years of cone and seed yields from 179 30- to 50-year-old western white pines (*Pinus monticola* Dougl.) representative of 13 geographic localities were compared. Each tree averaged 28 cones per tree, and each cone contained about 104 filled seeds. However, not only was annual cone production highly variable, but geographic localities and individual trees varied greatly in productivity within a given year. Recognition of these components of variation in cone production for western white pine can lead to maximal efficiency in cone collection.

Cone yields also varied among individual trees within localities (table 2). Differences in cone production of individual trees within localities were directly proportional to the effect of the seed year just as were differences in yield among localities. Moreover, differences in cone yield per year among individual trees depended on the overall yield of the locality. Although cone production by trees in high-yielding localities differed by as much as 100 cones per tree for each year, trees within localities of low mean yield showed little difference in production. Thus, each locality contained trees that characteristically produced few cones, even in good seed years; differences among localities apparently resulted from varying proportions of trees that produced large crops of cones in generally high-yielding years.

Of the exogenous factors that affect cone yield, the one that cannot be assessed at this time, due to lack of data, is the influence of microsites on the yield of trees within localities. However, other factors can be assessed; tree age, elevation, and latitude can be related to mean cone yield by correlation analyses (table 3). Although unequal sampling and possible intercorrelations among age, elevation,

Table 3.--*Correlation of tree age, tree elevation, and locality latitude with cone yield of: individual trees; trees within localities; and localities*

Cone yield	Tree age	Tree elevation	Locality latitude	d.f.
	----*Correlation coefficient, r*----			
Individual trees	0.33**	0.42**	--	177
Trees within localities (pooled r)	.45**	.44**	--	166
Localities	--	--	.66*	11

**Significant at the 1 percent level of probability.
*Significant at the 5 percent level of probability.

and latitude make interpretation difficult, cone yield per tree and locality appears weakly associated with tree age and tree elevation. Significance of the indicated correlation between cone yield of localities and locality latitude is doubtful because values for Boulder Creek (highest latitude and high elevation) exert enough influence to inflate the correlation coefficient over the 5 percent level of significance.

Yield of Seeds Per Cone

The average wind-pollinated cone yielded approximately 104 filled seeds; thus, each tree produced nearly 3,000 filled seed per year. However, yields of filled seeds per cone were positively associated with the yield of cones (r = .79, significant at the 1 percent level of probability). Mean yield of filled seeds per cone thus varied according to seed years (table 4), localities (table 5), and trees within localities (table 5). In fact, yields of seeds per cone ranged from 25 to 149 for two trees in different localities and in different seed years.

Exogenous variables cannot entirely account for the tremendous variation in total number of filled seed per tree. Tree 212 near Cedars Guard Station and tree 58 in the Crystal Creek area (see figure 1) outwardly were similar in terms of age, size, dominance, and local stand density (table 6). Although the cone yield of tree 212 was about one-half that of tree 58, the seed yield of 212 was less than one-fourth that of 58. Possible genetic control of these traits requires elucidation; their importance in seed orchards might be great.

Yields From Wind-, Cross-, and Self-Pollinated Cones

Statistical analyses (paired "t" tests) of balanced samples of filled seeds per cone (table 7) indicate that yields derived from self-pollinations were less (1 percent level of probability) than those of wind- or cross-pollinations; no differences were detected

Table 4.--*Mean yields of filled seeds per cone according to the seed year and the localities with the lowest and highest mean yield for each year*

	Yields per year		Yields per locality			
			Locality of lowest yield		Locality of highest yield	
Year	Trees observed	Mean (seeds/tree)	Trees observed	Mean (seeds/tree)	Trees observed	Mean (seeds/tree)
1950	17	77.3	3	28.0	1	156.0
1951	18	75.2	6	42.2	10	97.2
1952	8	77.5	6	72.0	2	94.0
1953	20	93.1	5	69.0	2	142.5
1954	25	149.5	3	114.3	11	164.1
1955	5	106.4	1	77.0	4	113.8
1956	14	82.6	4	75.8	4	88.7
1957	4	107.5	--	--	--	--
1958	17	124.2	5	106.2	2	177.5
1959	15	92.1	3	63.0	7	105.1
1960	8	61.0	2	50.0	4	62.5
1961	22	77.7	6	49.3	2	128.5
1962	32	94.4	2	41.5	3	151.3
1963	17	72.4	2	18.0	6	104.5
1964	18	130.5	1	37.0	1	147.0
1965	18	73.4	2	50.0	1	114.0
1966	21	98.7	2	61.5	2	123.0
1967	24	99.9	1	81.0	3	143.0

Table 5.--*Mean yields of filled seeds per cone according to the locality and tree within each locality with the highest and lowest mean yields*

Locality	Trees observed	Mean years of obser-vation	Mean (seeds/tree/year)	Yield per tree: Tree of lowest yield, Years observed	Tree of lowest yield, Mean (seeds/year)	Tree of highest yield, Years observed	Tree of highest yield, Mean (seeds/year)
Gold Center	6	5.5	70.6	7	50.7	5	93.8
Rainy and Randolph Creeks	5	6.2	85.0	6	45.8	5	116.4
Cedars Guard Station	8	6.4	90.9	8	24.8	5	133.4
Crystal Creek	11	10.1	97.8	6	52.3	7	112.7
Marble Creek	3	5.3	102.2	6	91.2	5	123.6
White Rock	5	8.0	112.5	9	75.1	11	155.6
Elk River	3	7.0	119.0	6	95.3	6	149.5

Table 6.--*Variation in cones, seeds, and total seed yield of several low and high yielding trees*

Item	Low yielding trees					High yielding trees				
	Tree number					Tree number				
	134	35	37	183	212	266	20	109	54	58
Locality	Rainy and Randolph Creeks	Gold Center	Gold Center	Cedars G.S.	Cedars G.S.	Marble Creek	Crystal Creek	Marble Creek	White Rock	Crystal Creek
Age in 1967	52	52	56	43	52	28	50	44	60	50
Year measured	1956	1951	1951	1956	1956	1961	1952	1959	1952	1952
Height (feet)	50	49	64	33	60	34	68	62	55	60
Diameter breast high (inches)	8.5	11.6	11.3	6.0	19.6	9.9	13.1	16.5	13.5	11.7
Dominance class	Inter-med.	Dom.	Dom.	Dom.	Dom.	Dom.	Dom.	Dom.	Dom.	Dom.
Stand density	Med.-dense	Open	Med.-open	Open	Open	Open	Med.-open	Open	Med.	Open
Mean cones/year	10.1	10.4	12.4	14.4	52.6	75.1	96.1	122.9	74.5	114.7
Years cones observed	7	10	11	10	11	7	11	8	14	18
Mean filled seed/cone	45.8	50.7	63.8	81.5	24.8	123.6	111.7	91.2	155.6	112.7
Years yield observed	6	7	5	6	8	5	7	6	11	15
Mean total filled seed/year	463	527	791	1174	1304	9282	10,734	11,061	11,592	12,927

between yields of the latter two groups. Lowered seed yields accompanying self-pollination in western white pine is well documented (Bingham and Squillace 1955; Squillace and Bingham 1958; Barnes, Bingham and Squillace 1962).

As noted previously (Bingham and Squillace 1955), the yield of total seeds (filled plus hollow) was essentially the same regardless of the type of pollination (table 7). The large proportion of hollow seeds that develop after self-pollination apparently result from embryo abortion because full-sized hollow seeds failed to develop following earlier failures in pollination, pollen tube growth, or fertilization in *Pinus sylvestris* L. (Sarvas 1962).

Table 7.--*Yield of filled and hollow seeds per cone from wind-, cross-, and self-pollinations. Comparisons are based on yields from trees on which observations were available in the same seed years*

Comparisons			Pollen type	Yield of seeds per cone		
Group	Trees observed	Years observed		Filled	Hollow	Total
A	28	9	Wind	111.2	12.0	123.2
			Cross	102.7	21.4	124.1
			Self	60.9	57.4	118.3
B	40	11	Wind	102.1	13.7	115.8
			Cross	94.4	21.3	115.7
			Self	--	--	--
C	141	12	Wind	--	--	--
			Cross	95.4	22.9	118.3
			Self	51.8	58.6	110.4

Approximately one-third of all control-pollinated cones, whether cross- or self-pollinated, failed to reach maturity. Since losses of cones due to insects, rodents, or breakage were known and minimal, losses of control-pollinated cones were almost entirely due to abortion of cones during development. Sarvas (1962) suggested that conelet abortion in pines is associated with high ovule abortion rates accompanying poor pollination. Conelet abortion of pines also appears to be associated with soil moisture stresses during the period of conelet elongation in *P. monticola*[2] and *P. radiata* D. Don (Pawsey 1960).

SUMMARY AND CONCLUSIONS

Between the ages of 30 and 50, western white pines average 28 cones per year. Each cone contains about 104 filled seeds which means that each tree produces about 3,000 filled seeds; however, tremendous variations occur. Annual production of cones is highly variable. Also, within a given seed year certain localities and individual trees within localities vary greatly in productivity. Of additional importance is the direct relationship between the proportion of filled seed and the size of the cone crop. Increased efficiency in seed collection can be realized by avoidance of low-yielding localities, trees and seed years. Also, by collecting only in high-yielding localities, cone and seed procurement can be maximized with a minimum of effort. This is particularly true when cone production is generally low.

It is further noteworthy that once techniques are mastered and proper timing is ascertained, yields derived from controlled pollinations of western white pine almost equal those of wind pollination.

---

[2]Ibid.

LITERATURE CITED

Barnes, B. V., R. T. Bingham, and A. E. Squillace.
1962. Selective fertilization in *Pinus monticola* Dougl. II. Results of additional tests. Silvae Genet. 11: 103-111.

Bingham, R. T., R. J. Olson, W. A. Becker, and M. A. Marsden.
1969. Breeding blister rust resistant western white pine. V. Estimates of heritability, combining ability, and genetic advance based on tester matings. Silvae Genet. 18: 28-38.

____________ and A. E. Squillace.
1955. Self-compatibility and effects of self-fertility in western white pine. Forest Sci. 1: 121-129.

Pawsey, C. K.
1960. Cone production reduced, apparently by drought, in the south-east of south Australia. Austr. Forest. 24: 74-75.

Sarvas, Risto.
1962. Investigations on the flowering and seed crop of *Pinus silvestris*. Commun. Inst. Forestalis Fenniae 53, 198 p.

Squillace, A. E., and R. T. Bingham.
1958. Selective fertilization in *Pinus monticola* Dougl. I. Preliminary results Silvae Genet. 7: 188-196.

AFLC/HAFB, Ogde

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field Research Work Units are maintained in:

- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)